[0022] FIG. **7** is a diagram of a vibration control pulse and the resulting vibration response according to an exemplary embodiment of the invention.

DETAILED DESCRIPTION

[0023] Exemplary and non-limiting embodiments of the invention provide an application program interface (API) and method for using the API to define and utilize a vibration control pulse **21**. The interface provides a means to accurately output short vibration effects, and also control the strength of the effects so as to provide sharp tactile feedback and to enable adjusting of tactile feedback. The vibration control pulse **21** is formed of a positive voltage start pulse and a negative voltage stop pulse with variable polarity to allow for two way control of vibrational direction. By selecting the parameters that define the precise shape and duration of the vibration control pulse **21**, the API can be employed to economically provide finely controllable haptic and tactile effects in user device, such as in a mobile phone or a gaming device.

[0024] Furthermore, exemplary and non-limiting embodiments of the invention disclose a robust control strategy, and parameters for implementing it, for driving vibration elements, such as rotating vibration motors, in an optimized manner. The control strategy is based on known (or assumed) inertial and electrical properties of the vibration actuator and properties of the driving electronics. Based on this data, a driving vibration control signal can be generated that results in an optimal, or near optimal, vibration output within given constraints. Specifically, short and sharp vibration effects can be outputted. In addition, the strength of the effects can be adjusted (via an intensity parameter), taking into account the specific constraints of the nature of controlling rotating motors without feedback.

[0025] With reference to FIG. **1**, there is illustrated a schematic diagram of the interaction of software and hardware elements that function together to implement an exemplary embodiment of the invention. In general, exemplary and non-limiting embodiments of the invention function to provide an application program interface (API) **49** to allow an executable program **47** to define a voltage control pulse **21** for controlling a vibration in a hardware component. While described with reference to use in a mobile phone, exemplary and non-limiting embodiments of the invention may extend to any and all mobile devices capable of executing software to control a vibrational element formed of hardware including, but not limited to, personal digital assistants (PDAs), gaming devices and the like.

[0026] As illustrated, a software toolkit **11** includes an application program interface (API) for specifying or otherwise defining a vibration control pulse **21**, described more fully below with reference to FIG. **2**. In an exemplary and non-limiting embodiment, the API may form part of a software development kit (SDK) including, but not limited to, S60 SDK 3.0. In practice, the API can be utilized by the software toolkit **11** to generate or otherwise create an application for execution by an operating system **13**. The API includes parameters to define, at least, the start of the vibration control pulse, the stop of the vibration control pulse, and the intensity of the vibration control pulse.

[0027] Operating system **13** operates to provide an environment within which an executable program, embodying the API, can be executed. Examples of an operating system **13** for implementing exemplary and non-limiting embodiments of the invention include the Symbian mobile operating system.

[0028] The operating system **13**, in particular programs executed within the operating system **13** environment, can further interact with an industry standard architecture (ISA) software (SW) **15**. The ISA SW **15** operates as a layer between the operating system **13** and the hardware platform or elements on which a vibration is to be produced. While illustrated as separate elements, in practice, the functionality of the operating system **13** and the ISA SW can be combined so as to both execute implementations of the API and interact with the hardware **19**. Specifically, the ISA SW **15** outputs a digital signal indicative of the vibration control pulse **21** to be implemented in hardware **19**.

[0029] Audio digital signal processor (DSP) **17** receives the output from the ISA SW **15** and applies a battery compensation function to reduce variability in battery voltage. In practice, the battery voltage in mobile devices can vary considerably. As the desired vibration control pulse **21** is a function of a nominal vibration voltage, described more fully below, such battery voltage variations can result in undesirable vibration voltage variation. In an exemplary and non-limiting embodiment, the Audio DSP **17** applies linear battery compensation to reduce battery voltage variability.

[0030] The signal output from Audio DSP **17** forms the input to the hardware **19**. Specifically, the signal received from the Audio DSP is a time varying vibration control pulse **21** that is employed to drive a vibration module. More particularly, as described more fully below with reference to FIG. **4**, the vibration control pulse drives a vibration element **48** for providing tactile feedback or other vibratory information to the user of a mobile device **41**. Examples of such vibration elements include, but are not limited to, haptic actuators, particularly those embedded in haptic displays.

[0031] With reference to FIG. **2**, there is illustrated a vibration control pulse **21** according to an exemplary and non-limiting embodiment of the invention. Typical vibration control pulses utilized in the art are formed of a unit step increase in voltage from a base level to a constant activation level followed, after a time interval, by a unit step decrease back to the base level. The resulting vibrational effect produced by such a signal tends to start slowly and stop quickly.

[0032] As illustrated, vibration control pulse **21** is formed of a start pulse **23** and a stop pulse **25** separated by a nominal voltage period **27**. Each transition from a zero or reference voltage, to start pulse **23**, to nominal voltage period **27**, to stop pulse **25**, back to zero voltage is a step function. The precise shape and proportions of the vibration control pulse **21** are controlled and defined by the parameters of the API **49**. These parameters include an intensity parameter, a vibration nominal voltage, a vibration nominal start pulse, and can include a vibration nominal stop pulse.

[0033] The intensity parameter is defined, in one exemplary and non-limiting embodiment, to range from a value of one to a value of one hundred with a value of fifty being nominal. The intensity parameter can additionally assume values between (for example) negative one and negative one hundred with negative fifty being nominal. In the instance that a negative intensity parameter is utilized, there is produced an opposite rotation, or polarity, of the vibration control pulse **21** whereby vibration control pulse **21** is reversed about the x-axis from that illustrated in FIG. **2**. Specifically, with ref-